LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

UCRL-PROC-206851

Chandra HETG Spectra of SS Cyg and U Gem in Quiescence and Outburst

C. W. Mauche, P. J. Wheatley, K. S. Long, J. C. Raymond, P. Szkody

September 28, 2004

The Astrophysics of Cataclysmic Variables and Related Objects
Strasbourg, France
July 11, 2004 through July 16, 2004

Chandra HETG Spectra of SS Cyg and U Gem in Quiescence and Outburst

Christopher W. Mauche[1], Peter J. Wheatley[2], Knox S. Long[3], John C. Raymond[4], and Paula Szkody[5]

[1]*Lawrence Livermore Nat'l Lab., 7000 East Ave., Livermore, CA, USA*
[2]*University of Leicester, Dept. of Physics & Astronomy, Leicester, UK*
[3]*STScI, 3700 San Martin Drive, Baltimore, MD, USA*
[4]*Center for Astrophysics, 60 Garden Street, Cambridge, MA, USA*
[5]*University of Washington, Dept. of Astronomy, Seattle, WA, USA*

Abstract. *Chandra* HETG spectra of the prototypical dwarf novae SS Cyg and U Gem in quiescence and outburst are presented and discussed. When SS Cyg goes into outburst, it becomes dimmer in hard X-rays and displays a dramatic shift in its relative line strengths, whereas when U Gem goes into outburst, it becomes brighter in hard X-rays and displays only a minor shift in its relative line strengths. In both systems, the emission lines become significantly broader in outburst, signaling the presence of high velocity gas either in Keplerian orbits around the white dwarf or flowing outward from the system.

The X-ray spectra of nonmagnetic cataclysmic variables provide important and unique information about the nature (the mass-accretion rate, emission measure distribution, density, velocity, abundances) of the boundary layer between the accretion disk and the surface of the white dwarf, where (nominally) half of the gravitational potential energy of the accreted material is released. The response of the boundary layer to changes in the mass-accretion rate is best studied in dwarf novae, where the mass-accretion rate varies systematically by a factor of $\sim 10^3$ between quiescence and outburst. Toward this end, we observed the prototypical dwarf novae SS Cyg and U Gem in quiescence and outburst with the *Chandra* X-ray Observatory High Energy Transmission Grating Spectrometer (HETGS). *Chandra* observations were obtained of SS Cyg in quiescence on 2000 August 24 and near the peak and early decline of a narrow outburst on 2000 September 12 and 14 (exposures of 47 and 96 ks), and of U Gem in quiescence on 2000 November 29 and at the peak of outburst on 2002 December 26 (exposures of 95 and 61 ks). The quiescent spectra of both systems are discussed briefly by Mukai et al. (2003), while a detailed account of the quiescent spectrum of U Gem is provided by Szkody et al. (2002). In this brief communication, we show the quiescent and outburst spectra of both systems in Figure 1 to highlight their similarities and differences.

In all cases, the X-ray spectra contain emission lines of a broad range of ions, consistent with the spectra of multi-temperature thermal plasmas. When SS Cyg goes into outburst, it becomes dimmer in hard X-rays and displays a dramatic shift in its relative line strengths (from predominately H-like to predominately He-like lines), whereas when U Gem goes into outburst, it becomes brighter in hard X-rays and displays only a minor shift in its relative line strengths. In both

cases, the emission lines become significantly broader in outburst, signaling the presence of high velocity gas either in Keplerian orbits around the white dwarf or flowing outward from the system. Such a wind is seen (in lower excitation lines) in the *Chandra* Low Energy Transmission Grating spectrum of SS Cyg in outburst (Mauche 2004).

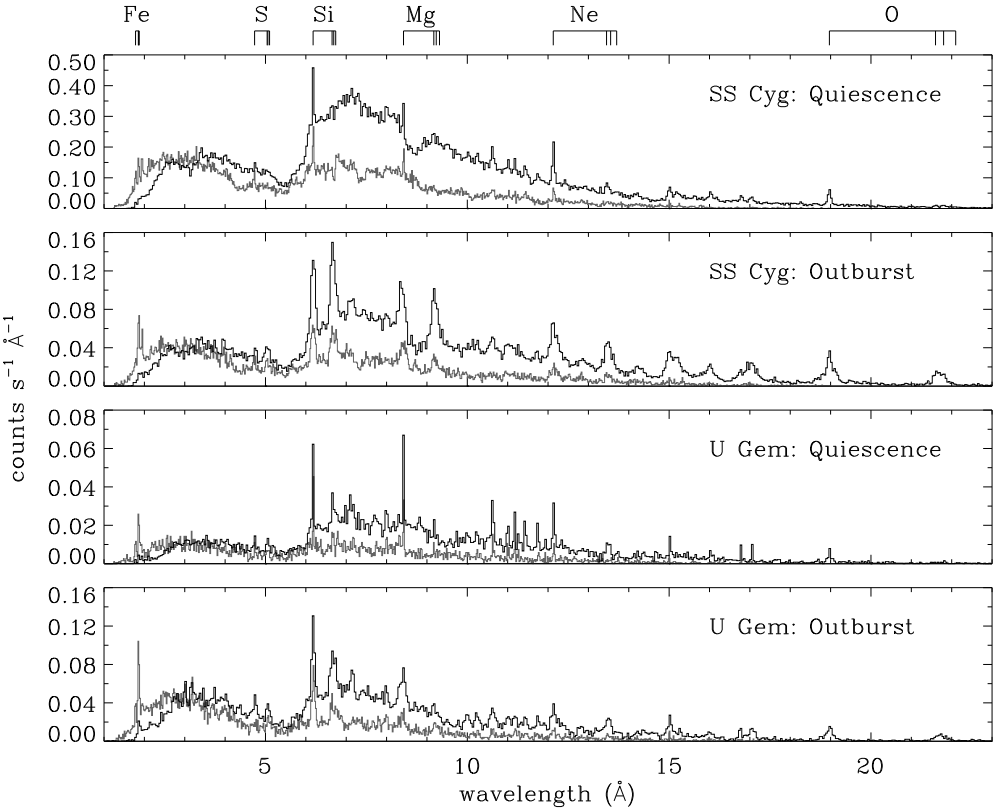

Figure 1. *Chandra* MEG (*upper histograms*) and HEG (*lower histograms*) count spectra of SS Cyg and U Gem in quiescence and outburst, with identifications of emission lines of H- and He-like ions of O, Ne, Mg, Si, S, and Fe.

Acknowledgments. Support for this work was provided in part by NASA through *Chandra* Award Numbers GO0-1094A and GO3-4025B issued by the *Chandra* X-ray Observatory Center, which is operated by SAO for and on behalf of NASA under contract NAS8-03060. This work was performed under the auspices of the US Department of Energy by University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

References

Mauche, C. W. 2004, ApJ, 610, 422

Mukai, K., Kinkhabwala, A., Peterson, J. R., Kahn, S. M., & Paerels, F. 2003, ApJ, 586, L77

Szkody, P., Nishikida, K., Raymond, J. C., Seth, A., Hoard, D. W., Long, K. S., Sion, E. M. 2002, ApJ, 574, 942